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(54) **COLLIMATOR FOR USE IN SUBSTRATE PROCESSING CHAMBERS**

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C23C 14/34	(2006.01)
H01J 37/34	(2006.01)
C23C 14/04	(2006.01)

(52) **U.S. Cl.**

CPC ***H01J 37/34*** (2013.01); ***C23C 14/046*** (2013.01); ***H01J 37/3408*** (2013.01); ***H01J 37/3447*** (2013.01)

(58) **Field of Classification Search**

CPC H01J 37/3441; H01J 37/3447; C23C 14/34

USPC 204/298.11

See application file for complete search history.

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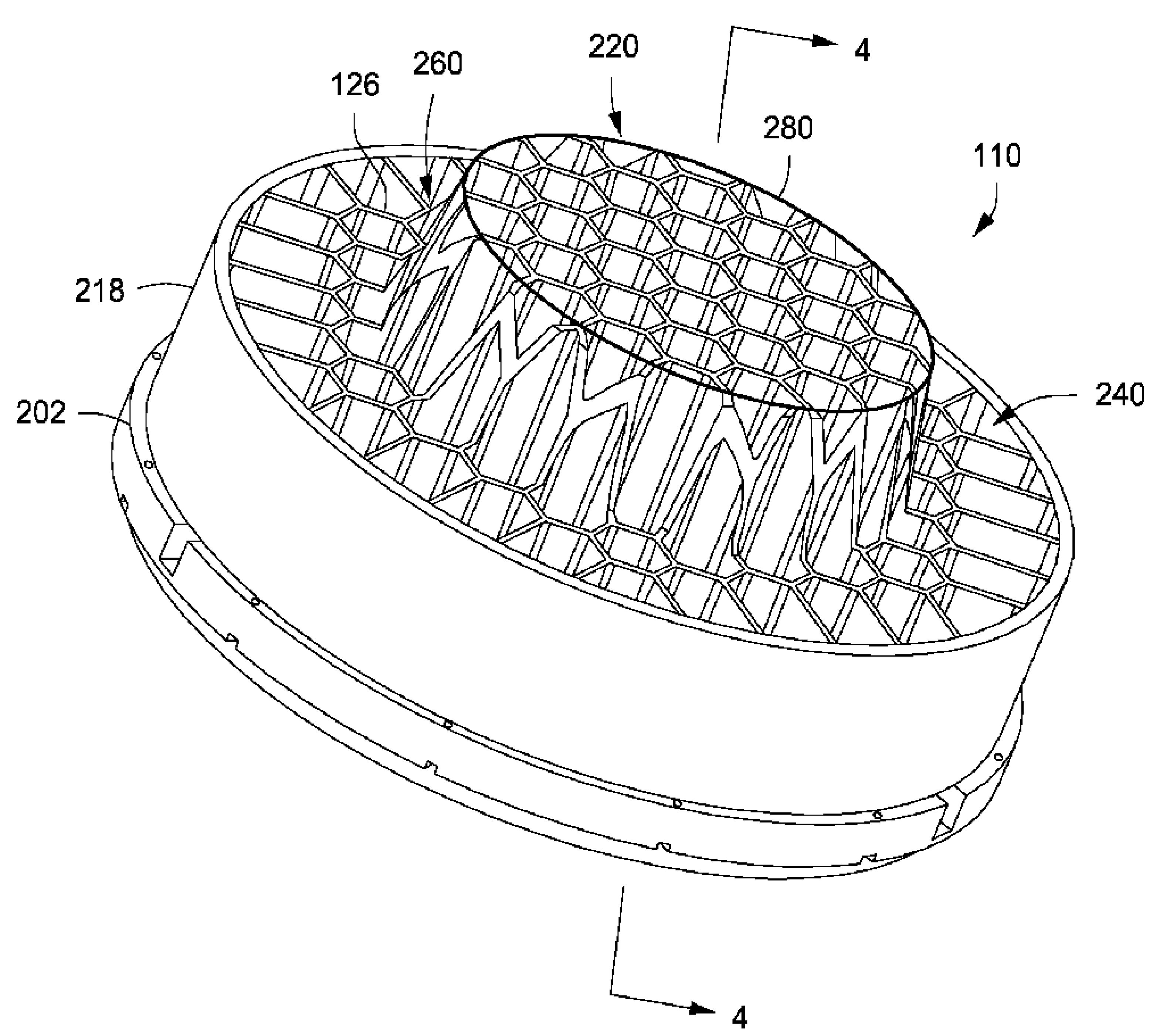
(57) **ABSTRACT**

Embodiments of collimators for use in substrate processing chambers are provided herein. In some embodiments, a collimator includes: a body having a central region, a peripheral region, and a transitional region disposed between the central and peripheral regions; a first plurality of apertures in the central region having a first aspect ratio; a second plurality of apertures in the peripheral region having a second aspect ratio less than the first aspect ratio; and a third plurality of apertures in the transitional region, wherein the third plurality of apertures are cut so the transitional region forms a conical shape surrounding the central region.

20 Claims, 3 Drawing Sheets



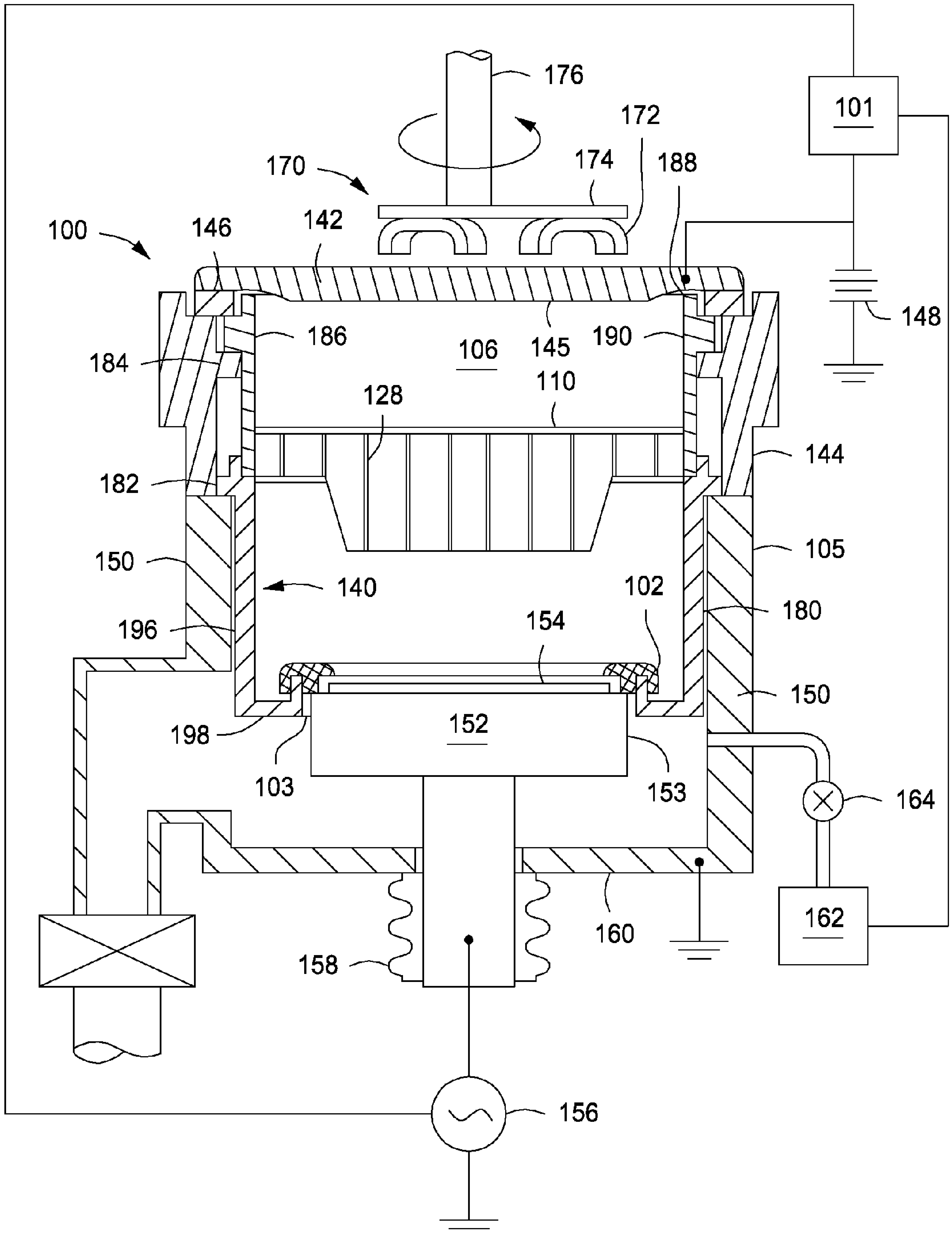

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FIG. 1

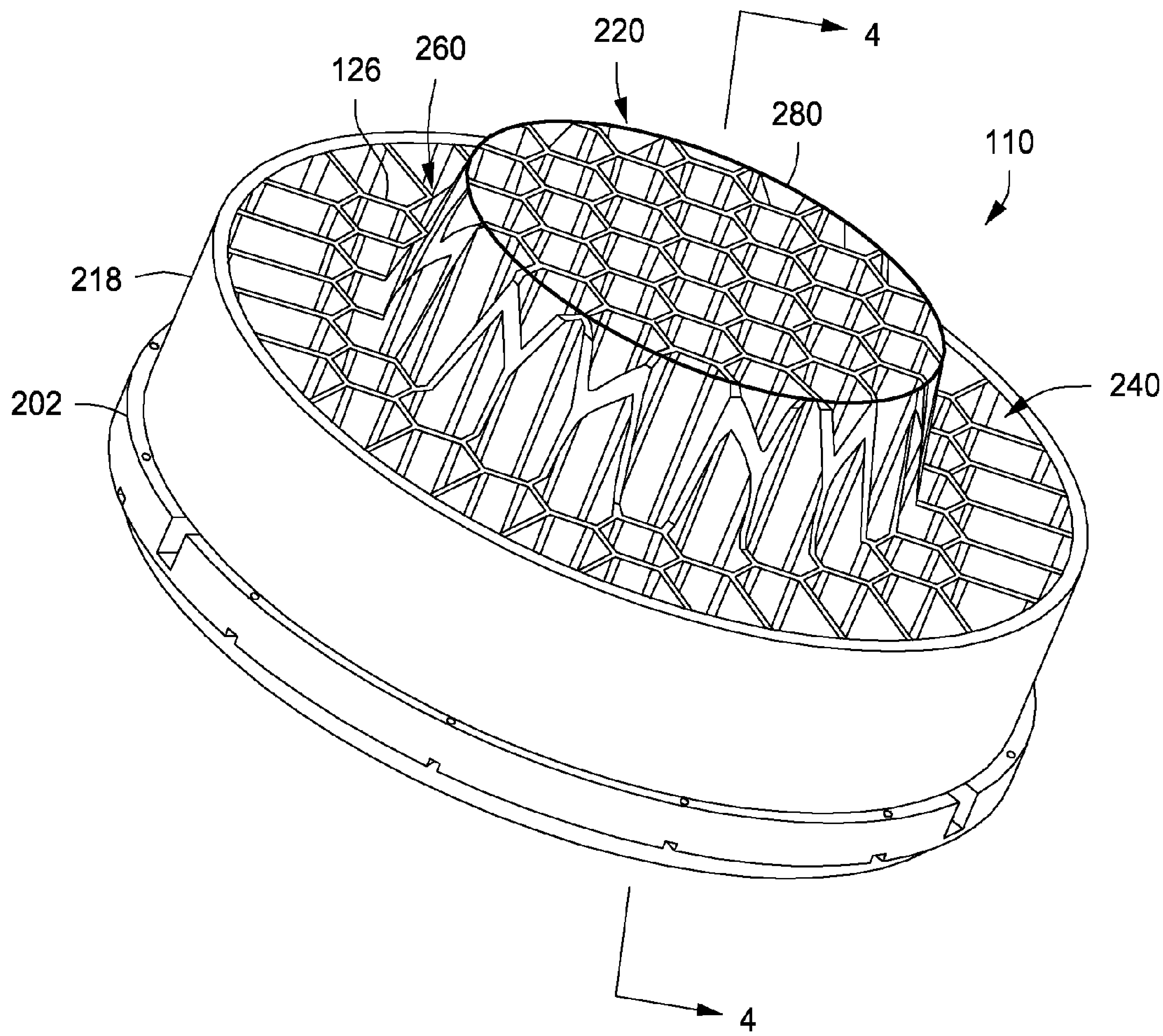

FIG. 2

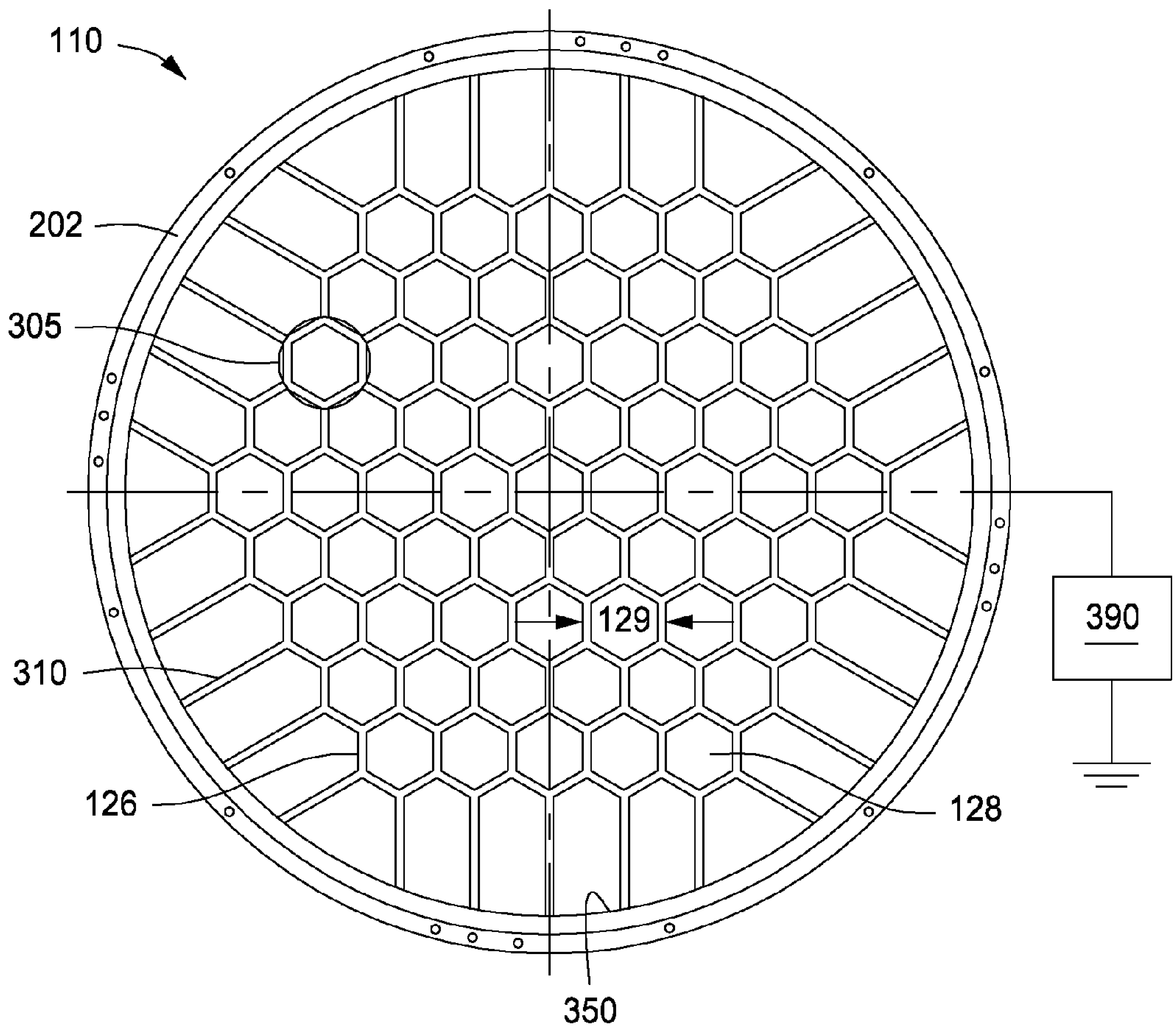
110
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FIG. 3

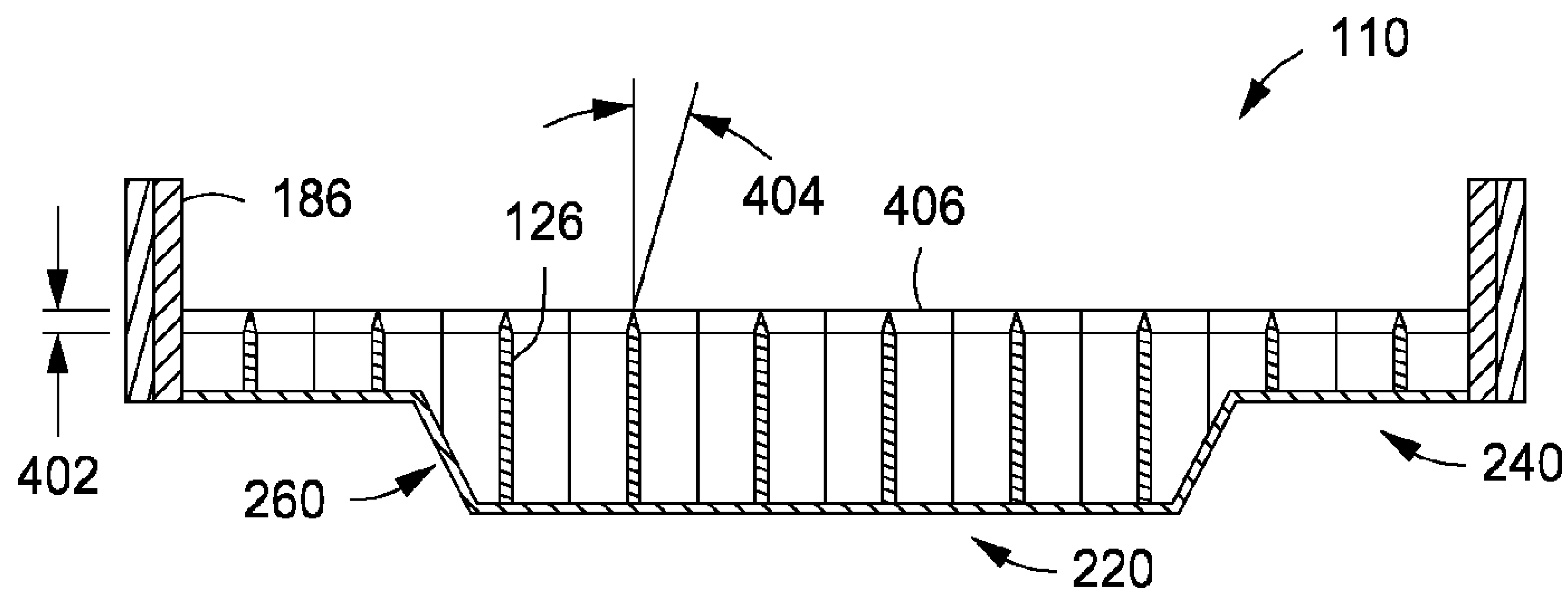
110
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FIG. 4

COLLIMATOR FOR USE IN SUBSTRATE PROCESSING CHAMBERS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims benefit of U.S. provisional patent application Ser. No. 62/085,009, filed Nov. 26, 2014, which is herein incorporated by reference in its entirety.

FIELD

Embodiments of the present disclosure generally relate to substrate processing chambers used in semiconductor manufacturing systems.

BACKGROUND

Reliably producing submicron and smaller features is one of the key technological challenges for the next generation of very large scale integration (VLSI) and ultra large scale integration (ULSI) of semiconductor devices. However, as the miniaturization of circuit technology continues, the shrinking dimensions of interconnects in VLSI and ULSI technology have placed additional demands on the processing capabilities. For example, as circuit densities increase for next generation devices, the widths of interconnects, such as vias, trenches, contacts, gate structures and other features, as well as the dielectric materials therebetween, decrease while the thickness of the dielectric layers remains substantially constant, with the result of increasing the aspect ratios of the features.

Sputtering, also known as physical vapor deposition (PVD), is a commonly-used method of forming metallic features in integrated circuits. Sputtering deposits a material layer on a substrate. A source material, such as a target, is bombarded by ions strongly accelerated by an electric field. The bombardment ejects material from the target, and the material then deposits on the substrate. During deposition, ejected particles may travel in varying directions, rather than generally orthogonal to the substrate surface, thus resulting in overhanging structures formed on corners of high aspect ratio features in the substrate. Overhang may undesirably result in holes or voids formed within the deposited material, resulting in diminished electrical conductivity of the formed feature. Higher aspect ratio geometries have a higher degree of difficulty to fill without voids.

Controlling the ion fraction or ion density reaching the substrate surface to a particular range may improve the bottom and sidewall coverage during the metal layer deposition process (and reduce the overhang problem). In one example, the particles dislodged from the target may controlled via a process tool such as a collimator to facilitate providing a more vertical trajectory of particles into the feature. The collimator provides relatively long, straight, and narrow passageways between the target and the substrate to filter out non-vertically travelling particles which impact and stick to the passageways of the collimator.

The actual amount of filtering accomplished by a given collimator depends at least in part on the aspect ratio of the apertures through the collimator. As such, particles traveling on a path approaching normal to the substrate pass through the collimator and are deposited on the substrate, which improves coverage of the bottom of high aspect ratio features. However, certain problems exist with the use of prior art collimators, which typically have an overall hexagonal shape. Unfortunately, PVD chambers with a prior art collimator leave a six-point deposition near an edge of the substrate due to shadowing of the corners of the hexagonal collimator.

Thus, the inventors have provided improved embodiments of apparatus with improved deposition uniformity.

SUMMARY

Embodiments of collimators for use in substrate processing chambers are provided herein. In some embodiments, a collimator includes a body having a central region, a peripheral region, and a transitional region disposed between the central and peripheral regions; a first plurality of apertures in the central region having a first aspect ratio; a second plurality of apertures in the peripheral region having a second aspect ratio less than the first aspect ratio; and a third plurality of apertures in the transitional region, wherein the third plurality of apertures are cut so the transitional region forms a conical shape surrounding the central region.

In some embodiments, a collimator for use in a substrate processing chamber includes a body having a central region, a peripheral region, and a transitional region disposed between the central and peripheral regions; a first plurality of apertures in the central region having a first aspect ratio; a second plurality of apertures in the peripheral region having a second aspect ratio less than the first aspect ratio; and a third plurality of apertures in the transitional region, wherein the third plurality of apertures are cut so the transitional region forms a conical shape surrounding the central region wherein the first plurality of apertures, the second plurality of apertures, and the third plurality of apertures are textured, and wherein upper portions of the first plurality of apertures, the second plurality of apertures, and the third plurality include a chamfer.

In some embodiments, a process chamber includes a chamber body defining an inner volume; a sputtering target disposed in an upper portion of the inner volume; a substrate support disposed below the sputtering target; and a collimator disposed in the inner volume between the sputtering target and the substrate support, wherein the collimator includes a body having a central region, a peripheral region, and a transitional region disposed between the central and peripheral regions; a first plurality of apertures in the central region having a first aspect ratio; a second plurality of apertures in the peripheral region having a second aspect ratio less than the first aspect ratio; and a third plurality of apertures in the transitional region, wherein the third plurality of apertures are cut so the transitional region forms a conical shape surrounding the central region.

Other and further embodiments of the present disclosure are described below.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present disclosure, briefly summarized above and discussed in greater detail below, can be understood by reference to the illustrative embodiments of the disclosure depicted in the appended drawings. However, the appended drawings illustrate only typical embodiments of the disclosure and are therefore not to be considered limiting of scope, for the disclosure may admit to other equally effective embodiments.

FIG. 1 depicts a simplified schematic cross-sectional side view of a process chamber in accordance with the some embodiments of the present disclosure.

FIG. **2** depicts an isometric bottom/side view of a collimator in accordance with some embodiments of the present disclosure.

FIG. **3** depicts a top view of a collimator in accordance with some embodiments of the present disclosure.

FIG. **4** depicts a cross-sectional side view of the collimator of FIG. **2**.

To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements which are common to the figures. The figures are not drawn to scale and may be simplified for clarity. Elements and features of some embodiments may be beneficially incorporated in other embodiments without further recitation.

DETAILED DESCRIPTION

Embodiments of collimators, such as those used for microelectronic device fabrication of semiconductor substrates, are provided herein. Collimators as disclosed herein advantageously improve deposition uniformity across a substrate to be processed.

Embodiments of the present disclosure are illustratively described herein with respect to a physical vapor deposition (PVD) chamber. However, the inventive collimator may generally be used in any substrate processing chamber to filter non-vertically traveling particles. FIG. **1** illustrates a processing chamber **100** (e.g., a PVD chamber) suitable for sputter depositing materials and having a collimator **110** disposed therein in accordance with embodiments of the present disclosure. Illustrative examples of suitable PVD chambers which may be adapted to benefit from the disclosure include the ALPS® Plus and SIP ENCORE® PVD processing chambers, both commercially available from Applied Materials, Inc., Santa Clara, of California. Other processing chambers available from Applied Materials, Inc., as well as from other manufactures, may also be adapted in accordance with the embodiments described herein.

The chamber **100** has a chamber body **105** defining an inner volume **106**. The chamber body **105** includes a grounded chamber wall **150** and a grounded conductive adapter **144** disposed above the grounded chamber wall **150**. In some embodiments, the processing chamber **100** includes a process kit **140** having a lower shield **180**, an upper shield **186**, and a collimator **110**. The processing chamber **100** also includes a sputtering source, such as a target **142** having a sputtering surface **145**, and a substrate support **152**, for receiving a substrate **154** thereon, having a peripheral edge **153**. The substrate support **152** may be disposed within the grounded chamber wall **150**.

The target **142** is supported by the grounded conductive adapter **144** through a dielectric isolator **146**. The target **142** comprises the material to be deposited on a surface of the substrate **154** during sputtering, and may include copper for depositing as a seed layer in high aspect ratio features formed in the substrate **154**. As used herein, the term aspect ratio refers to the ratio of the height, length, or depth of an element to the width of the element. In some embodiments, the target **142** may also include a bonded composite of a metallic surface layer of sputterable material, such as copper, and a backing layer of a structural material, such as aluminum.

In some embodiments, the substrate support **152** supports a substrate **154** having high aspect ratio features to be sputter coated, the bottoms of which are in planar opposition to a principal surface of the target **142**. The substrate support **152** has a planar substrate-receiving surface disposed generally parallel to the sputtering surface of the target **142**. The substrate support **152** may be vertically movable through a bellows **158** connected to a bottom chamber wall **160** to allow the substrate **154** to be transferred onto the substrate support **152** through a load lock valve (not shown) in a lower portion of the processing chamber **100**. The substrate support may then be raised to a deposition position as shown.

In some embodiments, processing gas may be supplied from a gas source **162** through a mass flow controller **164** into the lower portion of the processing chamber **100**. A controllable direct current (DC) power source **148**, coupled to the processing chamber **100**, may be used to apply a negative voltage or bias to the target **142**. A radio frequency (RF) power source **156** may be coupled to the substrate support **152** to induce a DC self-bias on the substrate **154**. In some embodiments, the substrate support **152** may be grounded. In some embodiments, the substrate support **152** may alternatively be electrically floated.

In some embodiments, a magnetron **170** is positioned above the target **142**. The magnetron **170** may include a plurality of magnets **172** supported by a base plate **174** connected to a shaft **176**, which may be axially aligned with the central axis of the processing chamber **100** and the substrate **154**. The magnets **172** produce a magnetic field within the processing chamber **100** near the front face of the target **142** to generate plasma so a significant flux of ions strike the target **142**, causing sputter emission of target material. The magnets **172** may be rotated about the shaft **176** to increase uniformity of the magnetic field across the surface of the target **142**.

In some embodiments, the processing chamber **100** may include a grounded lower shield **180** having a support flange **182** supported by and electrically coupled to the chamber wall **150**. An upper shield **186** is supported by and electrically coupled to a flange **184** of the conductive adapter **144**. The upper shield **186** and the lower shield **180** are electrically coupled as are the conductive adapter **144** and the chamber wall **150**. In some embodiments, both the upper shield **186** and the lower shield **180** are comprised of stainless steel. In some embodiments, the processing chamber **100** may include a middle shield (not shown) coupled to the upper shield **186**. In some embodiments, the upper shield **186** and lower shield **180** may be electrically floating within the processing chamber **100**. In some embodiments, the upper shield **186** and lower shield **180** may alternatively be coupled to an electrical power source.

In some embodiments, the upper shield **186** may have an upper portion which closely fits an annular side recess of the target **142** with a narrow gap **188** between the upper shield **186** and the target **142**, which is sufficiently narrow to prevent plasma from penetrating and sputter coating the dielectric isolator **146**. The upper shield **186** may also include a downwardly projecting tip **190**, which covers the interface between the lower shield **180** and the upper shield **186** to prevent bonding of the lower shield **180** and the upper shield **186** by sputter deposited material.

In some embodiments, the lower shield **180** may extend downwardly into a cylindrical outer band **196**, which generally extends along the chamber wall **150** to below the top surface of the substrate support **152**. The lower shield **180** may have a base plate **198** extending radially inward from the cylindrical outer band **196**. The base plate **198** may include an upwardly extending cylindrical inner band **103** surrounding the perimeter of the substrate support **152**. In some embodiments, a cover ring **102** rests on the top of the cylindrical inner band **103** when the substrate support **152** is in a lower, loading position and rests on the outer periphery of the substrate support **152** when the substrate support is in an upper, deposition position to protect the substrate support **152** from sputter deposition.

The lower shield **180** encircles the sputtering surface **145** of the target **142** facing the substrate support **152** and also encircles a peripheral wall of the substrate support **152**. The lower shield **180** also covers and shadows the chamber wall **150** of the processing chamber **100** to reduce deposition of sputtered deposits originating from the sputtering surface **145** of the target **142** onto the components and surfaces behind the lower shield **180**. For example, the lower shield **180** can protect the surfaces of the substrate support **152**, portions of the substrate **154**, the chamber wall **150**, and the bottom wall **160** of the processing chamber **100**.

In some embodiments, directional sputtering may be achieved by positioning the collimator **110** between the target **142** and the substrate support **152**. The collimator **110** may be mechanically and electrically coupled to the upper shield **186**. In some embodiments, the collimator **110** may be coupled to a middle shield (not shown), positioned lower in the processing chamber **100**. In some embodiments, the collimator **110** may be integral to the upper shield **186**. In some embodiments, the collimator **110** is welded to the upper shield **186**. In some embodiments, the collimator **110** may be electrically floating within the processing chamber **100**. In some embodiments, the collimator **110** may be coupled to an electrical power source. The collimator **110** includes a plurality of apertures **128** to direct gas and/or material flux within the chamber. In some embodiments, the apertures **128** may have a hexagonal shape, as illustrated in FIGS. **2-4**.

FIG. **2** is an isometric view of the collimator **110** in accordance with some embodiments of the present disclosure. FIG. **3** is a top plan view of a collimator **110** which may be disposed in the processing chamber **100** of FIG. **1**. In some embodiments, the collimator **110** has a generally honeycomb structure having walls **126** separating apertures **128** in a close-packed arrangement. An aspect ratio of the apertures **128** may be defined as the depth of the aperture **128** (equal to the length of the collimator at a specific location) divided by the width **129** of the aperture **128**. In some embodiments, the thickness of the walls **126** is between about 0.06 inches and about 0.18 inches. In some embodiments, the thickness of the walls **126** is between about 0.12 inches and about 0.15 inches. In some embodiments, a circle **305** circumscribing each of the apertures **128** may have a diameter of 1.5 inches. In some embodiments, the collimator **110** is comprised of a material selected from aluminum, copper, and stainless steel.

The honeycomb structure of the collimator **110** may serve as an integrated flux optimizer **310** to optimize the flow path, ion fraction, and ion trajectory behavior of ions passing through the collimator **110**. In some embodiments, the walls **126** adjacent to a shield portion **202** have a chamfer **350** and a radius. The shield portion **202** of the collimator **110** may assist in the installation of the collimator **110** in the processing chamber **100**.

In some embodiments, the collimator **110** may be machined from a single mass of aluminum. The collimator **110** may optionally be coated or anodized. Alternatively, the collimator **110** may be made from other materials compatible with the processing environment, and may also be comprised of one or more sections. Alternatively, the shield portion **202** and the integrated flux optimizer **310** are formed as separate pieces and coupled together using suitable attachment means, such as welding. In some embodiments, the walls **126** of the collimator **110** may be textured (e.g., bead blasted) to improve adhesion of high stress films (e.g., copper alloys) to the walls **126**.

In some embodiments, the collimator **110** may be electrically biased in bipolar mode so as to control direction of the ions passing through the collimator **110**. For example, a controllable direct current (DC) or AC collimator power source **390** may be coupled to the collimator **110** to provide an alternating pulsed positive or negative voltage to the collimator **110** so as to bias the collimator **110**. In some embodiments, the power source **390** is a DC power source.

The collimator **110** functions as a filter to trap ions and neutrals emitted from the material from the target **142** at angles exceeding a predetermined angle, near normal relative to the substrate **154**. The apertures **128** of the collimator **118** may have an aspect ratio change across the width of the collimator **110** to allow a different percentage of ions emitted from a center or a peripheral region of the material from the target **142** to pass through the collimator **110**. As a result, both the number of ions and the angle of arrival of ions deposited onto peripheral regions and center regions of the substrate **154** are adjusted and controlled. Therefore, material may be more uniformly sputter deposited across the surface of the substrate **154**. Additionally, material may be more uniformly deposited on the bottom and sidewalls of high aspect ratio features, particularly high aspect ratio vias and trenches located near the periphery of the substrate **154**.

FIG. **4** is cross-sectional view of the collimator **110** shown in FIG. **2**. The collimator **110** includes a body **218** having central region **220** having a first plurality of apertures with a high aspect ratio, such as from about 2.5:1 to about 3.3:1. In some embodiments, the first plurality of apertures in the central region have an aspect ratio of about 3.3:1. The aspect ratio of a second plurality of apertures of the collimator **110** decreases in a peripheral region **240**. In some embodiments the second plurality of apertures in the peripheral region **240** have an aspect ratio of about 1:1. A higher aspect ratio allows for more apertures in the central region **220** of the collimator **110**. In some embodiments, for example, the central region **220** includes 61 apertures.

In some embodiments, the radial aperture decrease of the collimator **110** is accomplished by providing a transitional region **260** disposed between the central region **220** and the peripheral region **240**. The third plurality of apertures are cut along a predetermined angle so the transitional region **260** forms a conical shape surrounding the first plurality of apertures. In some embodiments, the predetermined angle may be between 15° and 45°. The transitional region advantageously provides a circular profile **280** of apertures in central region **220**, which overcomes the six-point deposition near an edge of the substrate **154** due to shadowing caused by corners of a conventional hexagonal collimator.

Upper portions of the walls **126** of the apertures **128** have a chamfer **406** to decrease a rate at which the apertures **128** are clogged by sputtered material. The chamfer **406** extends a predetermined distance **402** into the aperture **128** and is formed at a predetermined angle **404**. In some embodiments, the predetermined distance **402** is between about 0.15 inches to about 1 inch and the predetermined angle is between about 2.5° and about 15°. In some embodiments, the predetermined distance **402** and the predetermined angle **404** are about 0.15 inches and 15°, respectively. In some embodiments, the predetermined distance **402** and the predetermined angle **404** are about 1 inch and 2.5°, respectively.

Thus, embodiments of a cooled process tool adapter and process chambers using same have been disclosed herein. The cooled process tool adapter advantageously facilitates supporting a process tool in a process chamber while removing heat from the process tool generated during use.

While the foregoing is directed to embodiments of the present disclosure, other and further embodiments of the disclosure may be devised without departing from the basic scope thereof.

The invention claimed is:

1. A collimator for use in a substrate processing chamber, comprising:

a body having a central region, a peripheral region, and a transitional region disposed between the central and peripheral regions;

a first plurality of apertures in the central region having a first aspect ratio;

a second plurality of apertures in the peripheral region having a second aspect ratio less than the first aspect ratio; and

a third plurality of apertures in the transitional region, wherein the third plurality of apertures are cut so the transitional region forms a conical shape surrounding the central region,

wherein the central region has a circular edge formed by the transitional region.

2. The collimator of claim **1**, wherein the first plurality of apertures, the second plurality of apertures, and the third plurality of apertures are textured.

3. The collimator of claim **1**, wherein the third plurality of apertures are cut at a predetermined angle of 15 to 45 degrees.

4. The collimator of claim **1**, wherein the first plurality of apertures includes 61 apertures.

5. The collimator of claim **1**, wherein upper portions of the first plurality of apertures, the second plurality of apertures, and the third plurality of apertures include a chamfer.

6. The collimator of claim **5**, wherein the chamfer is about 2.5° and has a length of about 1 inch.

7. The collimator of claim **5**, wherein the chamfer is about 15° and has a length of about 0.15 inches.

8. The collimator of claim **1**, wherein an aspect ratio of the first plurality of apertures is 3.3:1.

9. The collimator of claim **1**, wherein each of the first plurality of apertures, the second plurality of apertures, and the third plurality of apertures is hexagonal.

10. The collimator of claim **1**, wherein a circle circumscribing each of the first plurality of apertures has a diameter of about 1.5 inches.

11. A collimator for use in a substrate processing chamber, comprising:

a body having a central region, a peripheral region, and a transitional region disposed between the central and peripheral regions;

a first plurality of apertures in the central region having a first aspect ratio;

a second plurality of apertures in the peripheral region having a second aspect ratio less than the first aspect ratio; and

a third plurality of apertures in the transitional region, wherein the third plurality of apertures are cut so the transitional region forms a conical shape surrounding the central region,

wherein the first plurality of apertures, the second plurality of apertures, and the third plurality of apertures are textured,

wherein upper portions of the first plurality of apertures, the second plurality of apertures, and the third plurality of apertures include a chamfer, and

wherein the central region has a circular edge formed by the transitional region.

12. The collimator of claim **11**, wherein the third plurality of apertures are cut at a predetermined angle of 15 to 45 degrees.

13. The collimator of claim **11**, wherein the first plurality of apertures includes 61 apertures.

14. The collimator of claim **11**, wherein the chamfer is about 2.5° and has a length of about 1 inch.

15. The collimator of claim **11**, wherein the chamfer is about 15° and has a length of about 0.15 inches.

16. The collimator of claim **11**, wherein an aspect ratio of the first plurality of apertures is 3.3:1.

17. The collimator of claim **11**, wherein each of the first plurality of apertures, the second plurality of apertures, and the third plurality of apertures is hexagonal.

18. The collimator of claim **11**, wherein a circle circumscribing each of the first plurality of apertures has a diameter of about 1.5 inches.

19. A substrate processing chamber, comprising:

a chamber body defining an inner volume;

a sputtering target disposed in an upper portion of the inner volume;

a substrate support disposed below the sputtering target; and

a collimator disposed in the inner volume between the sputtering target and the substrate support, wherein the collimator comprises:

a body having a central region, a peripheral region, and a transitional region disposed between the central and peripheral regions;

a first plurality of apertures in the central region having a first aspect ratio;

a second plurality of apertures in the peripheral region having a second aspect ratio less than the first aspect ratio; and

a third plurality of apertures in the transitional region, wherein the third plurality of apertures are cut so the transitional region forms a conical shape surrounding the central region,

wherein the central region has a circular edge formed by the transitional region.

20. The substrate processing chamber of claim **19**, wherein an aspect ratio of the first plurality of apertures is 3.3:1.

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